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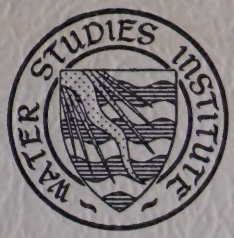

RESEARCH NEEDS IN RELATION TO WATER

A Symposium

WATER STUDIES INSTITUTE
SASKATOON, CANADA

No. 1

November 1964

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A Symposium

held

October 25, 1963

at the

University of Saskatchewan

WATER STUDIES INSTITUTE
SASKATOON, CANADA

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DEDICATION

This initial publication of the Water Studies Institute is dedicated to Dr. Hank Wolbeer who, on February 7th, 1963, first suggested the formation of an organization to encourage water studies and whose conviction and energy contributed considerably to the establishment of the Water Studies Institute a few months before his death on March 24th, 1964.

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FOREWORD

It is with considerable pleasure that I am writing this foreword to the first publication of the Water Studies Institute, and it may, perhaps, be in order to give a brief outline of the formation of the Institute.

As pointed out in the Dedication of this report, the Institute grew out of a suggestion made early in 1963 by the late Dr. Wolbeer of the Saskatchewan Research Council. A series of informal discussions followed, culminating on March 14th, 1963 in a meeting of some forty people, all interested in some aspect of water. Those attending this meeting were drawn from such diverse organizations as the Sask. Department of Natural Resources, Canadian Wildlife Services, National Research Council, Saskatchewan Research Council, Meteorological Branch of the Canada Department of Transport, Canada Agriculture Research Station, P.F.R.A., and the University of Saskatchewan. Resulting from this meeting, a committee of five was established, the understanding being that this committee should look further into the need for and possible benefits arising from the formation of some type of organization in Saskatchewan having the study of water problems as its focus; the committee was also asked to give attention to the name, to the terms of reference, and to the structure that such an organization might have, and if possible to arrange for a symposium, outlining research needs in the broad field of water studies, to be held in conjunction with a business meeting in the fall of 1963. The make-up of this committee was Professor C. R. Forsberg, Department of Civil Engineering, Professor J. M. Murray, Department of Agricultural Engineering, and myself (the chairman), Department of Geological Sciences, all of the University of Saskatchewan, Dr. J. Maybank, Physics Division, Saskatchewan Research Council, and Mr. L. G. Sonmor of the Canada Agriculture Research Station. We met many times during the course of that summer both as a full committee and in subcommittees dealing with various specific topics. We talked with many people and contacted many others to sound out opinions as to the need for some type of organization, its structure, duties and name. Finally we approached Dr. J. W. T. Spinks and Dr. T. E. Warren to ask whether the University of Saskatchewan and the Saskatchewan Research Council, respectively, would give such an organization their blessing, and would also give it status by participating in its activities.

Reaction to our proposals was sympathetic on every hand and we felt sufficiently encouraged to go to the business meeting, following the symposium reported here, and recommend the establishment of a Saskatchewan Water Studies Association. The recommendation was favourably received, and the slate for members for the first full committee, as proposed by our planning committee, was elected. Thus the Saskatchewan Water Studies Association, the name of which was subsequently changed to Water Studies Institute by unanimous agreement of the present committee, was formed. It may be worthwhile here to explain briefly that the name change

was made, not because a different style of organization was, or is, envisaged; the word 'Saskatchewan' was dropped because it was felt undesirable to limit the activities of the group to this province only, while the word 'Institute' was substituted for 'Association' because of its more formal connotation, and because it is believed that as the organization becomes known and established its activities will broaden over the coming years and may be better encompassed by the name 'Institute' rather than by 'Association'.

The topic chosen for the first symposium was that of Research Needs in Relation to Water, and so the papers which follow pose questions rather than answer them, suggest research rather than report it, ask for information rather than supply the facts. Nevertheless it is believed that underlining the needs of the various disciplines engaged in research on water in one of its varied aspects served a very useful purpose at the time, and that there is sufficient material here to continue to interest and to provoke thought: so it is hoped that this publication may be of value to many.

Finally I would like to take this opportunity to thank all those who helped to make our first symposium the success it undoubtedly was. Professors Forsberg and Murray, Dr. Maybank and Mr. Sonmor of the original planning committee carried the lion's share of the load. Dr. D. M. Gray acted on Professor Murray's behalf on numerous occasions. Dr. T. P. Pepper, first chairman of the Water Studies Institute, gave continuing support and contributed many worthwhile ideas, in addition to undertaking the formidable ask of acting as chairman for the symposium. The symposium's value lay in the high quality of the presentations and my sincere gratitude goes to all those who took time to prepare their talks and to participate in this, our first public venture, and particularly to Dr. T. E. Warren whose opening remarks keynoted the entire proceedings.

T. E. W. Nind[1]
Chairman, Planning Committee.

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1. Department of Geological Sciences, University of Saskatchewan, Saskatoon.

INTRODUCTORY REMARKS

T. E. Warren[1]

You will recall that a meeting was held on March 14th of this year to consider formation of a water studies association. About 30 to 40 people attended the meeting which was held in the Saskatchewan Research Council building. All of these had an interest in some aspect of water science. Dr. Pepper was convener and chairman of the meeting and conducted a discussion on the objectives and organization of the proposed association.

At the meeting a committee was elected to develop the concept of a Saskatchewan Water Studies Association. The members of the committee were Professors Forsberg, Gray and Nind, Dr. Maybank and Mr. Sonmor. The committee has worked actively since the time of its appointment. It has obtained the approval of the University and the Saskatchewan Research Council to form an association and has formulated plans for the association to the point where an organizational meeting can be held. This meeting, as you know, will be held this afternoon at 3:00 p.m.

One of the major functions of the association will be to define the needs for research in the various fields of water science. The program for this morning and the early afternoon will be devoted to a series of short papers in which each of the authors will state his ideas on research that needs to be done. The papers fall into two groups, the first group on what we could call water occurrence and the second on water use. The water occurrence group comprises papers on meteorology, surface water, soil moisture and underground water. Under the heading of use we can classify the papers on vegetation, animals, fish, wildlife, drinking quality for man and municipal and farm water supply.

It would be fair to describe this as a "live" program in the sense that it is completely unrehearsed and I do not believe that the committee or the chairman know exactly what the authors are going to say. I am certainly looking forward with great interest to their opinions on the research that is needed in the field of water science.

1. Director, Saskatchewan Research Council, Saskatoon, Saskatchewan.

ON HYDROMETEOROLOGICAL RESEARCH REQUIREMENTS

G. A. McKay[1]

The rains and snows which replenish our lakes, rivers and soil come from the atmosphere — hence our interest in hydrometeorology. The measure in which the atmosphere provides dictates our water problems, and in measure our economy. Alternating periods of drought and moisture excess are common to our temperate climate, and have helped shape our way of life. It is understandable, then, that hydrometeorological research is of substantial importance to prairie water problems.

Hydrometeorology, as we know it in North America, has been developed to meet flood forecasting and design requirements. It is, by nature, interdisciplinary so that some of the proposed research may also qualify under other disciplines. However there are fields in which its role is relatively distinct. One field in which it holds prominence is the study of storm rainfall. Notable activities shared with others are problems of snow accumulation and melt, consumptive use, and free-water evaporation. Hydrometeorological research requirements are seemingly limitless, possibly because of its many associations. They may be simply stated as:

1) increased knowledge of atmospheric processes;

2) improved measurement of meteorological parameters;

3) improvement in our ability to interpret meteorological measurements.

Although brief, these three categories could of course embrace the whole field of meteorology.

The problem is simplified somewhat by restricting it to Saskatchewan.

DROUGHT

Our water supplies which are basic to our existence are largely dependent on the generosity or whim of a fickle atmosphere. Eighty per cent of the streamflow in our major rivers is obtained from snow melt from the Rockies. About eighty per cent of the water stored in dugouts is obtained from the prairie snow pack. Our use of stored water is in inverse proportion to rainfall. Water supply reservoirs must be designed to carry us through the periodic droughts which can be expected. Their storage capacity is dependent on drought characteristics of which we are poorly informed. It is surprising that, with our heritage of drought, so little is known about drought frequency characteristics. We know their effects qualitatively but statistical information on intensity, duration, area frequency are required for design. Knowledge of atmospheric circulations leading to drought may be of inestimable value in predicting their start, persistence or finish.

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1. Hydrometeorologist, seconded from the Meteorological Branch of the Department of Transport to P.F.R.A., Regina.

EVAPORATION

Drought alerts us to water conservation in many forms. The estimated annual free-water evaporation loss from the future South Saskatchewan Reservoir would provide Regina with a water supply for ten years. Improved means of estimating evaporation losses from reservoirs are required both for design and allocation of water. While much research is being done on evaporation, this is far from being a closed book. The major consumer on many reservoirs is evaporation. Research into the reduction of this loss, or evaporation suppression is a field which may be very rewarding to water-short peoples.

STORM RAINFALL

Hydrometeorology is concerned with other aspects in the design of water-supply reservoirs, most notably in spillway design. In many instances spillway design is based on streamflow statistics. In the absence of suitable streamflow statistics and in the design of major structures, hydrometeorology may play a significant role. These roles in principle are sound, but much research is required for satisfactory application.

Probable Maximum Precipitation

An example is the use of probable maximum precipitation which is used to obtain the probable maximum flood for spillway design of structures such as the South Saskatchewan Dam. This value is obtained from consideration of the atmospheric moisture supply and storm efficiency. The procedures are based on many assumptions which require verification. Some of these are:

1) a ramp-type lifting of air is assumed in most instances; this may be quite inadequate for the prairie thundershowers which provide much of our rain. — Research is required into the physical structure of storms, convergence-divergence patterns, moisture and temperature advection, the influence of orography, etc.;

2) a 12-hour continuing-maximum dew point is used as a basis of moisture maximization — a much smaller period is possibly warranted for thunderstorm-activity; information on the increase and decay of moisture supply to the storm, and its importance should be studied. Also there is a need for improved measurement of atmospheric moisture, particularly for sounding equipment;

3) an arbitrary ceiling has been placed on moisture supply by hydrometeorologists. A revision of this ceiling would alter most probable-maximum-rainfall calculations for North America. The ceiling appears to be based on the ramp-type storm model — is it applicable to other models which may exist?

The many assumptions concerning the above, orography, etc. require much closer scrutiny.

Statistical Probable Maximum Precipitation

An alternative procedure is to predict probable upper limits of rainfall statistically using extreme values. This procedure has apparent weaknesses when rare events are being considered. Improved knowledge of statistical populations or procedures which would aid in defining the return periods of rare events with more certainty would be of assistance in many design studies.

SNOW

Frequently design floods are based on snow melt as well as rainfall. In these instances a knowledge of snow-pack statistics and snow-melt rates is essential. These have not been studied methodically for the plains. We in Saskatchewan are interested in both the plains snow pack and the mountain pack. Snow-pack measurements on the plains have not been very useful in runoff prediction — perhaps new sampling approaches are warranted. Knowledge of the albedo and its variation, radiation, atmospheric moisture, wind and temperature fields over snow are required in increasing detail. As with water we lack instruments which give truly representative measurements of areal evaporation loss from snow. The relationships between rate of snow melt and run-off begs investigation as does the formation, properties and effects of related features such as soil frost seals.

CONSUMPTIVE USE

Net evaporation loss and consumptive use are being investigated under the aegis of many disciplines. Much of the research in this field is wanting when it comes to aerial interpretation. Changes in atmospheric-water-vapour content as air moves over an area offers one means of measuring losses from large areas. This procedure should be of particular importance in semi-arid areas in which we live. It may require improved sounding networks and humidity sensors, but could give very realistic information in a field which currently weighs heavily on empiricism.

NETWORKS

Our meteorological networks have been designed with many users in mind. They may not be providing all the information required for prudent exploitation of our water resources. Research concerning the design of networks is required so that we may obtain an optimum of information and economy. It seems reasonable that network planning should also include meso and micro networks which inform us as to the frequency, depth, area, duration characteristics of the prairie thundershowers which provide most of our moisture rainfall-runoff information, and information on apparent climatic anomalies. The most interesting thunderstorms presently have a habit of slipping through our network almost unseen. The network research should also concern itself with northern Saskatchewan where little is known of the permanence or recharge characteristics of waters for which

so much is being planned. The network should concern itself with short-period rainfall-intensity data. There are only two or three locations in the Province with more than ten years of this type of observation which is vital in the design of culverts, sewers, etc.

The requirements go on and on because of the breadth of the field covered by hydrometeorology.

1) Artificially induced precipitation merits further consideration, particularly in the headwaters of the Saskatchewan River. An appraisal of the potential, as interpreted by hydrologists, is warranted. Increased yields have been generally expressed as a percentage of gauge catch. Hydrologists need to express this in terms of increased runoff to obtain a more realistic valuation.

2) Climatic trends, particularly in climatic fringe areas, warrant attention as do the modifying influences produced by man. The effects of weather control, if and when it is practiced, may be very pertinent to our future water supplies.

3) Land management, management of forests, use of snow-fencing, and topography, etc. to aid in snow storage may help augment our sometimes meagre water supplies.

4) Little attention has been paid to the importance and possible use of dew.

INSTRUMENTS AND MEASUREMENTS

A recent investigation of rain gauges concluded "such devices may perform differently . . . . . The true areal precipitation is unknown"(1). This finding is similar to those of other investigators. In most measurements we know what the instrument is doing — we seldom know how to interpret it in terms of true point of areal values. Much is required in instrument design. We require instruments which are accurate, robust, economical, capable of operating unattended for long periods for remote installation — instruments for measuring precipitation are in particular demand. Radar offers excellent opportunities for areal measurements. Improvements in design, interpretation and economy would be welcomed.

Microclimatic research and research in interpretation of records is needed. With energy budget and mass transfer techniques being used increasingly, there is a need to improve our interpretation of solar radiation and bright sunshine records in terms of energy, to know the response of various surfaces to the various components of the radiative energy exchange; to understand the turbulent transfer of heat and vapour over various surfaces and over widely varied meteorological conditions. Improved sensors are needed for the solution of many of these problems. It is important that we know how to express the findings of such investigations in terms of area. The areal variations, effects of elevation, slope aspect exposure — on most parameters remains a research problem.

The Automatic Picture Transmission System (APTS) to be flown on NIMBUS and TIROS VIII satellites should yield interesting information on our weather and snow. Interrelative techniques are required.

In short, the research needs appear limitless. Many of the problems quoted above are common to other areas and are being investigated elsewhere. However, geographic and climatological differences require that we must solve these problems as they affect Saskatchewan. Some of the research may have to await the development of instruments, or funds. We should not wait however for certain basic research. Drought studies are long overdue. We should be planning measuring networks for our northern areas now so that we may use our resources more intelligently in the future. Since much of our effort must be expended in conservation and water supply reservoirs, we should make every effort to ensure that design criteria are based on sound premises, and that every means of conserving supplies is fully investigated. The atmosphere provides us with water — frequently this is in meagre supply. We can in large measure, overcome this fickleness of nature by intelligent planning and design based on hydrometeorological research.

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A SUMMARY OF RESEARCH NEEDS IN SURFACE WATER HYDROLOGY

E. F. Durrant[1]

If we didn't need water to live, or if we had water a-plenty on the Prairies we wouldn't be here today. But we do need water — lots of it — and our surface water supplies are very limited. These two factors, water supply and water demand provide a useful basis for discussing research needs in surface water hydrology.

In this summary, I would like to mention first some interesting research possibilities directed toward a reduction of water demands. Then I'll attempt to list possible areas of research aimed at a better understanding of our surface water supplies. I'll close with a few comments on data networks.

Our major rivers service only a limited area of Saskatchewan. For the remainder of the province and for the remainder of this discussion, run-off from small streams and small watersheds must be emphasized.

REDUCING WATER DEMANDS

The technical literature and the popular press are loaded with stories of great river basin developments, "All-American Canals," long water pipelines, and the like. These things are not free — no matter who builds them — and the cost of the water supplies thus provided must be paid by someone. There may be a limit to how much grandiose development we can afford. Therefore we must think seriously on the question, "Must we continually find and develop new sources of water to meet our growing water demands?"

There's a famous line of Jimmy Durante's that goes like this, "Don't raise that bridge boys — lower the river." Perhaps we should follow his advice and give just as much thought to reducing our water demands as we do to increasing our water supplies. Perhaps we should face up to the fact that, living in an arid area, we may have to develop an economy which uses less water per capita than elsewhere.

Here are a few ways in which research might help us to reduce water use:

Economics

There is a tendency for governments to subsidize water supplies for municipal and industrial use. At artificially low prices heavy demands build up which require further public investment which, in turn, may perpetuate artificially low prices. Well-designed research into real water values and water's role as a "multiplier" in the economy might lead to more

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realistic water prices — or at least to penalties for over-use. Incidentally, water is now as high as 50c per 200 gallons at some community wells — approaching well-head oil prices.

Recirculation and Treatment

The only difference between drinking water and sewage effluent is that drinking water is a much weaker solution. Throughout the world, research is active into ways for removing objectionable components from the effluent so that it can be re-used. Research might reveal better ways of doing this under Prairie conditions. "Dry" industrial processes and air cooling should also be given some thought.

Sociological

Could people adjust to non-green parks, and gravelled front yards? Continued commitment of some of our best water to horticulture of questionable value may be a luxury we cannot afford 30 or 40 years from now. What sort of education and adjustment would be needed to accustom us to recreation areas more in keeping with our arid surroundings?

Control of Seepage and Evaporation

Leakage and evaporation from reservoirs and canals is costly. We need research which will tell us when it is economical to apply known techniques for their control. We could also use some better techniques.

Optimum Reservoir Size

We need criteria to guide us in striking a balance between over-large wasteful reservoirs (evaporation) and reservoirs too small to assure a given water supply. This is a complex function of streamflow, demand, reservoir depth-area characteristics, evaporation, seepage head, and up-stream regulation.

Stream Conveyance Losses

What causes stream conveyance losses; when are they at a maximum and when are they minimum? Reservoir operation could be planned to minimize these losses if they were predictable.

Water Harvesting

Instead of projecting long pipelines for pure water, should we study the economics of water harvesting? The late James G. Gardiner used to claim that his barn roof with eavestroughs and a good cistern would water some 30 head of cattle. Recent work in Tempe, Arizona is aimed at finding economic ways of creating an impervious surface over several acres. Perhaps some of our small towns could store harvested water and use it to dilute the cheaper brackish groundwater which seems to be available most anywhere.

There are no doubt many more fruitful research possibilities in this field. It is ironic that progress over 50 years has increased our consumption from 10 gallons per capita per day to 150 g.p.c.d. Now we need research to move us back to where we started from.

THE NATURE OF SURFACE RUN-OFF (STATISTICAL)

Much can be deduced about the availability of surface waters on watersheds of 50 square-miles and larger by statistical evaluation of streamflow observations which have been made in Saskatchewan since 1911. For watersheds smaller than 50 square-miles, we have very little data.

An understanding of run-off characteristics is fundamental to investments in water supplies for any purpose. Such an understanding is also essential to the proper design of works to utilize water. By improving our understanding then we assure ourselves of better water investments and water control works.

Research needs in the analysis of run-off statistics vary from south to north. In the short grass prairie area, we have good streamflow data but we also have three problems which make it difficult to use techniques developed elsewhere to analyze that data: these are fluctuating drainage areas, semi-arid conditions with large and variable soil storage (variable run-off response to rainfall), and the fact that 80% of prairie run-off is derived from shallow-pack snow melt — a phenomenon largely overlooked in the literature. In the parkland belt, the problems are similar but less complicated by data. In the Forest and Pre-Cambrian Shield areas there is no run-off data. The timid researcher could have a field day here because there is nothing to prove him wrong. Most of the following suggestions on research are aimed at the Prairie and Parklands.

Regional Run-Off Patterns

Streamflow measurement will always be done on a "sampling" basis. To help in assessing the yield of small ungauged streams, regional patterns must be sought in present run-off records. PFRA is now completing a "first approximation" study of this type. There is room for refinement.

Reliability of Run-Off

"What is the probability that this reservoir will be at a given level during the next 10 years?" "What is the probability that this ungauged stream will cease to flow for 35 consecutive months?" We need answers to these questions but presently available regional run-off studies provide only approximate answers. The research path which might be followed here is related to the next subject.

Persistence

Most of our water storage projects are designed to function safely during a drought period similar to the Thirties. We design for these condi-

tions merely because we know they have occurred. We need research which will tell us the probability of having a recurrence of this drought or a worse one in the next 10 years, and the next, and the next.

Other useful information may be obtained from streamflow records, for example:

Measures of Typical Hydrograph Shapes

The relationship of the mean daily flow to the instantaneous peak, and the relationship of peak run-off rates to total run-off volumes are useful. These have been studied for individual streams, but to my knowledge no attempt has been made to relate these characteristics to watershed and/or regional geomorphological characteristics.

Recession Curves

The rate at which streams recede after a flood follows the classical exponential decay curve. The slope of this curve should increase as the size of the watershed decreases. It should also be related to natural and artificial storage in the watershed as well as other measurable factors. If the shape of these recession curves could be inferred from watershed characteristics, the art of predicting flood flows would be advanced.

Regional Flood Peak Studies

PFRA has completed a "first step" flood peak analysis which can be used to estimate the occurrence probability of floods of various sizes on Prairie watersheds. There is room for refinement and improvement.

THE NATURE OF SURFACE RUN-OFF (THEORETICAL)

To a rational thinker it is quickly apparent that, given standard rainfall conditions, the variation in hydrographs from watershed to watershed should be related to measurable watershed characteristics such as size, slope, cover, land use, drainage density, aspect, latitude, regional geology, etc. A rational thinker might also ask "Why measure umpteen parameters, when streamflow measurements can themselves supply all the answers?" Well, streamflow data are expensive and will always be obtained on a sampling basis on large watersheds (50 square miles and better) and only rarely on small watersheds if present policies continue. If then, run-off characteristics can be deduced from measurable watershed characteristics, a great gap in our run-off knowledge can be filled. This is both an areal gap (thinking of small watersheds) and a time gap (thinking of all ungauged areas). Plugging the time gap is possible if good long-term precipitation data are available and if we can assume that all other significant parameters are known.

At the present time, experimental watersheds are too rare in Canada to permit statistical filling of the areal gap and they tend to be too rare to provide sound relationships for general application. In this work, the alternatives are (a) minimal instrumentation on many small watersheds, or (b) intensive instrumentation on a few.

The watershed research program presently proposed by the Saskatchewan Research Council is a compromise between these alternatives. Perhaps it will point the way to more fruitful research in this field.

Whether or not specific watershed research projects will add to our knowledge of run-off, there are many fringe benefits such as:

1) a better understanding of the close relationship between the shape of the hydrograph and physical features of the watershed;

2) guidance in planning land use to influence run-off characteristics;

3) a better understanding of the causes, effects, and control of stream erosion;

4) an excellent training ground for neophyte hydrologists in all phases of the hydrologic cycle;

5) development of better instrumentation to observe various parts of the hydrologic cycle;

6) and many others.

Before leaving this subject, it should be noted that the technical literature abounds with analyses of the many research watersheds in the U.S.A. But it is recognized that very little of this research has application in Prairie pothole country. It is also a fact that the hydrology of northern watersheds in and near the Shield is almost completely unstudied. What happens, for example, if your watershed is covered by lichen (having a nil evapotranspiration loss) and is founded on fractured basement rock? These northern watersheds will be used some day. It would be well to understand them before we start to abuse them.

DATA NETWORKS

A dissertation on hydrologic research needs would be incomplete without reference to our data networks. In the past, streamflow records have been kept at point A because someone asked for them. Unless that someone tells someone else to stop, those records will still be gathered in 1980. Locations for record-keeping have been selected without regard to statistical laws and sampling needs except for the controls that man's intuition automatically provides.

Immediate, rather than long term, needs for data have created further problems, for example:

1) Our water laws provide for licensing flows during the "irrigation season." As a result we have a host of part-year records and no hope of knowing what the flows were in the non-irrigation season.

2) Winter-flow records are scarce due to a lack of interest in the past, and a lack of suitable equipment for measuring under winter conditions.

3) The spring freshet tends to be well-documented but not the low-flow periods. Our low-flow records are very approximate. You might say that abundance is well documented, but scarcity is not considered worthy of measurement.

Research should be directed toward the following goals in order to overcome these inadequacies:

1) Standards for the design of data networks in the Prairie region.

2) Projection of water needs so that we know what kinds of data we will need 30 years from now.

3) Improvement of equipment to measure winter flows and low flows.

It is my personal opinion that a properly designed network would produce at least three times as much usable data without increasing our expenditures for data collection.

RESEARCH NEEDS IN GROUNDWATER HYDROLOGY

E. A. Christiansen[1]

GROUNDWATER HYDRAULICS

1) Permeability of aquicludes. The permeability of till, clay, and shale determine largely the rate of recharge to aquifer.

2) Groundwater movement

   (a) Rate of movement

   (b) Nature of movement—Effect of topography
   —Regional flow systems
   —Groundwater recharge and discharge areas

3) Application of pumping test formulas to glacial aquifer which do not comply with the assumptions on which the formulae are based.

4) Model studies such as electric analogs to study aquifer potential.

5) Elasticity of aquifers. Are artesian aquifers completely elastic? Does consolidation of the aquifer take place with declining head? If so, then the storage in the aquifers is diminished.

GROUNDWATER QUALITY

1) Groundwater chemistry. Basic research is required to determine geochemical environments and reactions which take place in the geological model between the recharge and discharge areas.

2) Desalinization. Inasmuch as most groundwater in Saskatchewan is saline, any economical method of desalinization will increase the safe yield.

WATER-WELL COMPLETION

Coarse silts and fine sands are very common sediments in Saskatchewan. Any improvement in well completion will greatly facilitate the production of groundwater from these sediments.

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RESEARCH NEEDS FOR GROUND WATER DEVELOPMENT

R. B. Godwin[1], N. E. Parsons[1], and T. W. Rey[1]

All water in Saskatchewan is important, in fact necessary, for the maintenance of a desirable standard of living. It would appear only natural that a well planned research program should be formulated to study the various phases of ground water development. Unfortunately, there is not an inexhaustable supply of water lying underneath the ground. The supply of this renewable resource is limited, and its use must be controlled so that the maximum benefit from a minimum amount of use is obtained from the available water supply.

Three basic questions must be answered to provide officials with adequate information to efficiently administer the proper use of this resource:

1) What quantity of ground water is available?

2) What is the quality of this available water?

3) What controls will be required to use this water to its optimum efficiency?

These three questions suggest many possibilities for future research. This paper will mention several which are of particular interest to the authors. Undoubtedly, the readers of this paper will be able to add many more.

WHAT QUANTITY OF GROUND WATER IS AVAILABLE?

In discussing the quantity of available ground water, reference must first be made to the individual well. Much additional research effort can be directed into methods of improved well construction and well completion. Many water supplies are not fully developed because of a lack of proper completion techniques, (e.g., more efficient methods of using gravel pack techniques, and of completing wells in the Belly River sands). It is, of course, possible that further improvement is not practical in some cases. Furthermore, these problems have probably been studied by other agencies both in Canada and other countries. A bibliography of these studies and a correlation with their practicability when applied to the conditions of Saskatchewan would undoubtedly aid the future development of individual wells.

Some thought should also be directed towards further education and training of the well drillers. They are in direct contact with ground water development and many do not fully understand the mechanics of this phenomenon. Several are still firm believers in the art of dousing or water-witching. Until these fieldmen can be re-educated so that they can use improved methods more efficiently, the research program is not complete.

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1. Water Rights Division, Saskatchewan Department of Agriculture, Regina.

The individual well is only a part of the development of an aquifer or ground water basin. Many questions immediately arise in any discussion of aquifer development. The location, extent and yield of individual aquifers must be determined. A less expensive method of estimating such aquifer reserves is needed. The Saskatchewan Research Council is presently doing an excellent job in preliminary mapping of their general location but additional information is needed to determine the aquifer yields or productivity. Present evaluations are tedious, lengthy, and approximate, and it is suggested that a more efficient method of evaluating aquifer potential might be developed. Such an approach, if successful, would be a major step ahead in ground water development.

Data is also needed to establish controls as to the number, type, spacing, etc. of wells best suited to each individual aquifer for optimum development. Pertinent to this subject is the problem of whether additional test wells will appreciably increase the degree of accuracy of measuring an aquifer's extent and yield. Studies of this type would establish a practical limit on the precision of data required for adequate administration purposes.

Further research is also required into the inter-effects of ground and surface waters in all areas of the province. There is a need for basic research into the effects that climate, vegetation, and soil factors will have upon ground water supply, storage, recharge, and conservation. Briefly then, the basic hydraulic and hydrological characteristics of the aquifers of Saskatchewan should be studied.

In future years, as the demand for ground water increases, there will be more extensive data required for the administration of water. It will be necessary to determine if ground water reservoirs are being maintained or depleted. This is necessary for good basin management. It will also be important to determine the degree of natural aquifer recharge and, in some instances, the effect of artificial recharge either from surface water or from other ground water sources. There is also the possibility that a large ground water depletion in some aquifers might cause areas of differential surface settlement and sufficient data must be gathered to define these situations.

In studying many of these problems it should also be remembered that additional field data may often yield the best solution. Too much textbook research with the resultant analysis based upon theory alone is not a substitute for the intelligent melding of theoretical studies with the results of field testing.

WHAT IS THE QUALITY OF THIS AVAILABLE WATER?

The foregoing discussion raises some of the problems which must be dealt with in assessing the quantity of available ground water. What should be said and done with respect to its quality? Other speakers in this seminar will probably discuss this aspect more fully but now would be an appropriate time to mention some of the problems which might be encountered.

There is a large, presently unusable, potential of mineralized water in the Province of Saskatchewan. Basic research is being conducted by several agencies into methods of purifying this supply. While this task is extremely important, research into the possible uses of presently available water of borderline quality should not be neglected. Such water might be used for some industrial uses, cooling, waste disposal, and other such uses and the more potable water could be used for domestic and municipal purposes.

The research now being undertaken to purify saline and mineralized waters may also be applied to provide economic methods of converting water of borderline quality in the glacial drift into more potable water. This research might have particular application to waters of questionable quality now being used by such Saskatchewan towns as Gravelbourg, Viscount and Lampman.

There are also areas of older bedrock in the southwest part of the province in which there is water of relatively low salinity. Waters such as these should be included in a ground water mapping program. Perhaps more liaison with oil companies to make better use of their test drilling data would be an advantage in conducting this work.

The practical limitations of water quality for consumptive use should be better defined both from a physical and chemical viewpoint. Some water, while it is not very palatable, is not detrimental to health. Water quality standards should be established now for all known users to determine what use can be made of each source.

There is also concern with safe guarding against the pollution of both present and potential ground water supplies. Such pollution could result from disposal of industrial and municipal waste waters. A pollution study program using tracer materials might better define the extent of this problem.

WHAT CONTROLS WILL BE REQUIRED TO USE THIS WATER TO ITS OPTIMUM EFFICIENCY?

The answers to questions raised previously will provide the answer to one general question, "How can optimum use be made of the ground water reserves of Saskatchewan?" This is the administrative problem. The Ground Water Conservation Act of Saskatchewan can not be efficiently administered until an attempt is made to estimate future uses. There should be research into both the future quantitative and qualitative demands for ground water and research into the proportions of this water which may be used domestically, municipally and industrially without fully depleting the reserves that are available. An economic forecast of the future value of ground water will also be necessary and, based upon this, the possibility and practicability of reserving certain ground water basins for future uses.

These are complex problems. They require research into existing ground water legislation in Canada, the United States and other countries to enable us to forestall, as far as possible, ambiguous regulations which may require future court actions to clarify and adjudicate disputes. Such research should enable the administrative officials to better provide for optimum use of the water available. For example, it should allow technical personnel to fully evaluate the effects of "mining" as opposed to "farming" the ground water in any one aquifer. It should also provide a means of evaluating the best methods of managing ground water basins.

SUMMARY

The suggested fields of research which have been covered in this paper may be summarized as follows:

Quantity of Available Water

1) Well Completion
   - —Gravel Pack Techniques
   - —Problems within specific aquifers

2) Aquifer Development
   - —Areal extent, thickness and yield
   - —Improved techniques of analyzing available data
   - —Methods of evaluating optimum aquifer development
   - —Induced recharge problems

3) Basic Hydrologic Research
   - —Effects of soil, climate, vegetation, etc.

Quality of Available Water

1) Present Use of Water
   - —Establishment of water quality standards
   - —Development and promotion of alternate uses for low quality water
   - —Investigation of water sources in older bedrock formations.

2) Demineralization
   - —Purifying presently unusable water

3) Pollution
   - —Aquifer pollution by natural or artificial means.

Optimum Use of Water

Effectiveness of Ground Water Legislation of other Administrative Agencies:

- —Conservation practices
- —Long range planning
- —Administrative controls.

FURTHER DISCUSSION OF RESEARCH NEEDS

An attempt has been made here to outline several fields of possible research necessary for both the present and future systematic development and administration of this renewal resource. Several of these projects would seem to be ideally suited to an university graduate study program. Such research, in co-operation with the interested agencies, would be very welcome to the field of ground water development.

It should be emphasized that additional research is needed in the field of semantics. After the work has been completed, after the estimates have been made, it is still necessary to advise the user what he has and how he can use it. Until this level of understanding is established, the research program is not complete.

THE DISTRIBUTION OF PLANT SPECIES IN RELATION TO WATER

R. T. Coupland[1]

The Department of Plant Ecology is engaged in research relating to the distribution, in relation to environment, of native and introduced plant species in the uncultivated lands of Saskatchewan. Although the environmental complex involves many factors and the effect of each individual factor is difficult to sort out, in numerous instances water is of prime importance.

The concept is well established that in the semi-arid grassland region of southwestern Saskatchewan deficiency of moisture is the most critical environmental factor limiting plant growth. However, deficiency of moisture supply to plants is not limited to arid and semi-arid regions. For example, in the bogs of northern Saskatchewan some of the plants rooted in water have difficulty in utilizing it because of its high viscosity associated with low temperature. Similarily, while moisture excesses greatly influence the distribution in growth of plants in northern Saskatchewan, there are many locations in the semi-arid grassland zone where excess moisture accumulates in depressions.

In understanding the relation of plant species to water it is necessary to have more information than is presently available concerning the vertical distribution of water within the soil and subsoil as well as its horizontal distribution in relation to topography and other physiographic features. Soil moisture distribution within the profile and its fluctuations in relation to climatic cycles is fairly well understood. However, little is known concerning the fluctuations in water table that may bring subterranean water within reach of plant roots. Only the extreme situations are well recorded. We have been more interested in the effect of drought on plants than in the effect of periods of excessive precipitation, and we have made observations on the effect of water tables that reached the surface but know nothing about those which do not.

Sufficient experience with irrigated crops suggests that high water tables may be just as detrimental to some species as a benefit to others.

In studying the relation of vegetation to environment the concept of the climax has emerged. This is the vegetation that reflects the natural environment in a region and is found on undisturbed normal upland soils. Positions drier than this have resulted from runoff from knolls, with the consequence that in depressions conditions are moister than the climax. While we have an accurate estimate of the amount of precipitation required to support the climax, we are deficient in information concerning how much precipitation is lost from the knolls and how much precipitation per unit area is received by the depressions. The factors that deter-

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1. Head, Department of Plant Ecology, University of Saskatchewan, Saskatoon.

mine redistribution of rainfall may be different from those that affect horizontal movements of snow. We need to know how much various environments are affected by addition of moisture from snow melt.

In some environments the vertical and horizontal distribution of water may act together in modifying the environment. For example, in the depression where runoff water accumulates a high water table may add further to the moisture supply. We need to know how much each of these factors contributes.

Other aspects of water research that may have an influence on plant distribution and growth include the effect of snow as a protective insulating layer. The depth of ice development on small water areas may be of consequence in relation to the erratic distribution of aquatic plants in such areas, but we have no information concerning the depth to which ice forms on prairie ponds.

An example will suffice to indicate that lack of information concerning distribution of water interferes with interpretations of the reasons for plant distributions. I am reminded of an occasion on which a soil scientist accounted for the abundance of aspen in the Dundurn sandhills on the basis of the high water table, while I explained it in relation to the greater supply of soil moisture associated with the sandy condition of the soil. Subsequent soil borings in groves of aspen in that region failed to reveal the presence of a water table, but who can say but that the water table does reach the roots of these plants intermittently.

The dominant plants of uncultivated lands are almost without exception perennials. In interpreting the influence of environment on perennial plants, allowance must be made for the whole period during which they develop. The present conditions are not sufficient for such interpretations. Indeed, the maximum and minimum fluctuations may be more important in determining the presence or absence of a species. It is just as important to explain why a species is not present in a site as it is to understand why it does thrive.

RESEARCH NEEDS IN SOIL SCIENCE IN RELATION TO WATER

D. A. Rennie[1]

The area of research needs in relation to water of vital interest to Soil Science is that involving use of water by vegetation and its storage in soils. The water entering into this portion of the over-all water cycle approximates 80% or more of the national water budget. While there is widespread popular acceptance of the importance of this portion of the water budget and while there is a great deal of information available, much of the data is vague and qualitative in nature and, in fact, many of the commonly accepted "facts" concerning the physical and biological aspects of soil moisture are not supported by factual evidence.

During the past few years we have embarked on an expanded program of soil moisture research in conjunction with our plant nutrient research program. The acquisition of a neutron moisture meter facilitated this expansion with little or no increase in staff requirements. While the emphasis to date has been placed on moisture investigations in association with our field fertility plot sites, a limited amount of complementary research data has been obtained under controlled conditions in the growth chamber. While these studies to date must be classified as exploratory only, in that very few conclusions concerning the complex soil/water/plant system can be made, the data does substantiate the need for an accelerated research program. In the next few minutes I am going, very briefly, to outline the more important areas of water research that we vitally need information on. These topics, because of human nature, will be coloured by my interest and experiences. It is most unfortunate that Dr. Hutcheon was not free to present this discussion. Undoubtedly certain areas of water research which are of vital concern have not been included.

THE NEED FOR COMPLETE ENVIRONMENTAL MEASURING DEVICES

With few exceptions, the majority of the data which we have accumulated on consumptive use of water show a reduction in the water requirement accompanying the use of phosphate fertilizers. Equally marked variations in evapotranspiration data can be attributed to changes in soil type (sub-group profile type, whose development has been largely influenced by slope and aspect), to the amount of stored water at the time of seeding in the spring, and to the distribution of rainfall during the growing season. However, where these experiments are laid down on the same sites in different years, markedly different results are obtained. For example, the evapotranspiration data obtained in one year may vary as much as 200% from that obtained on the same site a year or two later. Our inability to explain the influence of any single or multiple factor on consumptive use of water by wheat, is undoubtedly due in part to the fact that

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we are only maintaining what might be termed minimal measurements of environment. Without measuring devices that will enable us to measure on a twelve month basis soil and air temperature, wind velocity, solar radiation, free water evaporation, amount and intensity of both snow and rainfall, and perhaps relative humidity, there is little possibility of adequately interpreting data of this type. Our primary need, therefore, in our water research program, is the installation of what might be termed complete environmental measuring devices.

INFLUENCE OF ENVIRONMENTAL FACTORS ON ROOT DEVELOPMENT

Degree of exploitation of the soil by the plant roots markedly changes the influence of stored moisture and rainfall on plant growth. Little information is available on the influence of environmental factors on root development. We have data which indicates that roots will penetrate through dry soil into moist soil below, but for some unexplainable reason do not appear capable of withdrawing moisture. In certain circumstances, the plant can use water at tensions far in excess of the permanent wilting point (15 bar). Is this the reflection of very extensive root proliferation? The extent and distribution of the root system does not necessarily correlate with rate of water withdrawal, nor with changes in the moisture profile. These are only a few of the many anomalies that have appeared in the data obtained from our field plot locations. They clearly emphasize the need for a detailed investigation into the relationship between biotic factors, and availability of soil water to the plant.

INFLUENCE OF FERTILITY LEVEL OF SOIL ON RATE OF EVAPOTRANSPIRATION

As mentioned earlier, our experiments show a reduction in water requirements accompanying the use of phosphate fertilizers. We originally assumed that this was due to more efficient use of water by the fertilized plant during the early stages of growth. However, this assumption has not been confirmed in rate studies, where frequent measurements of changes in the moisture profile were conducted during the growing season. Further research is necessary to determine the reason for the change in evapotranspiration rates with changing fertility levels of soils. The only significant conclusion that can be drawn is that close attention must be paid to fertility levels in studies designed to determine consumptive use of water by crop.

THE SIGNIFICANCE OF PHYSICAL AND CHEMICAL FACTORS OF THE SOIL

The studies that we have conducted on selected soil sites within similarly managed farm units, indicate that the satisfactory interpretation of agrometeorological data is closely dependent on the soil. While we have not as yet sorted out the significance of physical and chemical factors of the soil, there is no doubt that these factors interact strongly wih climatic variables.

INFLUENCE OF SOIL MOISTURE ON AVAILABILITY OF PLANT NUTRIENTS

I have already noted that the fertility level of the soil markedly affects evapotranspiration ratios. A related area of study in which we are vitally interested is the influence of soil moisture on the availability of plant nutrients. In recent years we have accumulated limited information on phosphorus/moisture relationships in the soil. There is little doubt that the availability of soil phosphorus to the plant decreases rather rapidly as soil moisture stress increases. Phosphorus deficiency symptoms are much more prominent during dry than wet years. While it appears that the availability of other nutrients such as potassium, nitrogen, and certain other minor elements, are affected in a similar way, little confirmatory evidence is available. Certainly climatic conditions within critical growth periods must be pinpointed much more closely than at the present time if we hope to explain differences in response to fertilization under field conditions that occur from time to time. Lack of confidence in soil test data as a basis for making fertilizer recommendations is due, to a large degree to our lack of research information, and consequently, our understanding of the influence of moisture levels on availability of plant nutrients.

INFLUENCE OF OSMOTIC PRESSURE OF SOIL SOLUTION ON THE AVAILABILITY OF SOIL WATER

It is well known that the osmotic pressure of the soil solution directly influences the availability of soil water. While considerable research has been conducted in this area elsewhere, there is a need for further experimental work under the climatic and soil conditions existing in the province. For example, sufficient evidence has been obtained from the data accumulated from farmer samples submitted to the Soil Testing Laboratory to suggest that many of the salinity bench marks on which land use capabilities are currently being made must be modified, due primarily to climatic conditions existing here in the province.

THE NEED FOR IMPROVED INSTRUMENTATION

The need for improved instrumentation in studies involving water can not be over-emphasized. Much of the equipment needed in soil water investigations must be constructed in the laboratory. The integral parts of this equipment are, in some cases, quite expensive. For example, electric analogues have been developed for measuring both saturated and unsaturated flow. The use of gamma rays for measuring the water content of narrow layers in the soil appears to be the answer where in situ measurements are required. Satisfactory instrumentation is not as yet available to measure plant water deficits. There is a vast field awaiting investigation in the use of radio isotopes in soil water studies. The use of deuterium — or tritium — tagged water, coupled with O^{18} and C^{14}, could be used simultaneously to trace water movement, oxygen movement, carbon dioxide

movement and the influence of these factors on the uptake of phosphorus or other plant nutrients. Costly tracer equipment would be necessary for studies of this type.

RESEARCH ON WATER EROSION IS REQUIRED

Research on water erosion in its many aspects is vital to permanent agriculture in many areas of the province. This is a broad field of research necessitating close co-operation between the soil scientist and agricultural engineer.

EFFICIENCY OF MOISTURE STORAGE UNDER FALLOW CONDITIONS

Farmers spend several millions of dollars fallowing from one-third to one-half of their cropland each year. The summerfallow acreage has been increasing in spite of the statements of eminent scientists and administrators that this practice is costly and in many instances unnecessary. There is a vital need for research on efficiency of moisture storage under fallow conditions at selected soil sites in different parts of the province.

RESEARCH ON IRRIGATED SOILS AND THEIR ASSOCIATED DRAINAGE PROBLEMS IS ALSO NECESSARY

While most of my discussion has dealt with research needs associated with dryland agriculture where little or no water control is possible, this must not be construed as indicating we do not realize the need for research on irrigated soils, and their associated drainage problems.

I have purposely attempted to outline research needs in relation to water, which, when undertaken, will have immediate practical application. These must of necessity, be accompanied by fundamental studies on soil water in both unsaturated and saturated systems, and on the physics and thermodynamics of plant water.

MUNICIPAL WATER SUPPLY AND WASTE WATER DISPOSAL RESEARCH NEEDS CONCERNING WATER

B. M. Ellis[1]

Mr. Chairman and gentlemen:

I have spent some time contemplating the condensing of the various problems concerned with the subject; the research needs in relation to water in the overall field of municipal water supply and waste water disposal. As an engineer in private practice I am usually concerned with the selection of treatment processes to produce potable water and also to produce a proper treated waste effluent rather than the research needs in connection with these processes. For some time now I have felt that the research requirements for both the water and waste water field required a directing agency and I am most pleased to recognize the establishment of this group of individuals as being able to provide this leadership and I trust the work force to undertake research projects.

WATER SUPPLY FOR MUNICIPAL PURPOSES

In considering the production of drinking quality water first of all I would like to say that our firm as one of a number of engineering groups works to the United States Public Health Drinking Water Quality Standards as there are no officially adopted drinking water quality standards for the Province of Saskatchewan. The U. S. standards set limits on dissolved material in the water that our local waters exceed most of the time in some of the categories. It is therefore necessary to overlook the limitations set by the U.S. standards in selecting the method of treatment, as it is not usually financially possible for the smaller community to do anything about the off quality characteristics. In some instances waters are available with total dissolved solids that are very much in excess of the U.S. limits and there is simply no other source of water for this community. I understand from the program list that we are to hear more about drinking quality standards from Dr. Robertson.

Before outlining research needs in the specific field of municipal water supply, it is my feeling that a basic set of standards for water quality must be adopted to form a working base. This association, in my opinion, can provide the necessary authority to recommend adoption of such a set of standards after due consideration, and then can recommend adjustments to these standards as a true expression of current research findings or as a result of work that has been sponsored and/or carried out by this association.

From the physical side of the municipal water picture, continued research is required in the treatment field beyond the scope of the inventor or equipment manufacturer. For the most part the treatment of surface

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1. Director of Engineering, Underwood, McLellan and Associates Ltd., Saskatoon.

waters for municipal use follows the classic approach of coagulation, settling, filtration, chlorination, storage and distribution. Water softening and other chemical conditioning is practised in the larger communities. The use of the rapid sand filter took over from the older form of slow sand filter at the turn of the century and there are no slow sand filters now in operation in North America to my knowledge. The rapid sand method of filtration is an excellent mechanical device but it does have its limitations. Research is required in the field of rapid sand filtration to ensure the continued dependability of this technique. The annual and sometimes biannual upsets in the raw water quality of the South Saskatchewan River continue to penetrate the very adequate rapid sand filter plant of the City of Saskatoon and other communities located on either of the two Saskatchewan rivers. It is necessary during this quality change to simply tolerate the off specification water and increase the chlorine dose to protect the user.

The use of sludge blanket or upflow type pre-treatment water units has for the most part, replaced the conventional coagulation and settling basins of water treatment plants. These units for the most part provide excellent quality effluents but like the rapid sand filter, do have their limitations and can be upset. Further research into this method of penetrating water is urgently necessary for use by the smaller community. The use of poly electrolytes as a flocculant aid has been satisfactorily demonstrated as being of help in the clarification and filtering of water, however, further practical research is required to develop their usefulness. I define practical research as the testing and the experimenting done in close relationship with the operation of a treatment plant, rather than the laboratory development work such as must go into the development of these new polymers.

Groundwaters, with a very high total dissolved solids continue to be used particularly in our smaller communities, and the economical development of ways to desalinize these brackish waters should receive our attention. The Office of Saline Waters of the United States Department of the Interior has a large program of research work underway in this field. Their efforts should be monitored and companion research work undertaken by this association. It is my understanding that this United States agency contracts out research assignments, either as original ideas or on specific projects and this association may wish to pursue this approach to this subject.

WASTE WATER DISPOSAL

The municipally generated waste waters in Saskatchewan are becoming more complex as industrial expansion occurs. There is a long list of items which constitute potential pollutants and active research is required to develop new methods of treating the wastes that accompany each new industry. The partial or complete treatment of industrial wastes prior to disposal into a municipal system or directly into a water course, should be the rule rather than the exception. The municipalities, in the western provinces particularly, are usually faced with the treatment of all industrial wastes that are discharged into their sewers.

It may be beyond the scope of this association to act as a clean stream committee, but the preservation of pollution-free waters depends greatly on the establishment and enforcement of pollution abatement works operated to achieve certain results. It is suggested therefore that this group could form the authority for the establishment and adoption of standards of treated waste waters from municipal works. Upon adoption, the standards would require continuing review and revision, and together with research directed to specific problems unique to the prairies, would provide the required leadership in pollution control.

In regard to some of the specific problems that require continuing research, I would name the lagoon as one and the subject of oxygen transfer by mechanical and diffused air methods as a second. The lagoon method of municipal waste water disposal is a relatively recent technique and there is much to be discovered about the biological action that takes place in one. Certain theoretical and experimental information is known concerning the oxygen transfer into water but the present transfer efficiency being tolerated in operating plants is very low. An improvement in the efficiency could result in significant savings in operational costs to the municipal owners of treatment works.

In summary gentlemen, I find a need for standards in drinking water quality and in the permissible pollutional strengths of waste water treatment plant effluents. This organization I feel can act as an advisory authority to establish and recommend the adoption of sets of standards in this regard. I see a number of specific research projects in the field of municipal water supply and waste water disposal. I also see a need for leadership in organizing the research requirements for our local conditions and to coordinate the research carried out for our own purposes with that of others.

Gentlemen, I thank you for your attention.

FARM WATER PROBLEMS HINDERING MODERNIZATION

Walter Nemanishen[1]

The value of water under pressure and a plumbing system in the farm home cannot be estimated by the cost of the installation. It adds health and happiness to the life of every member of the farm family. It saves labor and time, and increases livestock and poultry production.

Each farmer except in unique circumstances is responsible for his own water supply and must obtain it within the boundaries of his own property. Shallow wells, deep wells, cisterns or dugouts, are the usual sources of water. But, on many farms, these sources provide water in either insufficient quality or quantity.

The quantity of water required every day depends on the size of the farm family and the animal population. Individual needs are as shown below:

TABLE I — FARM WATER REQUIREMENTS

Family	50 gallons per person
Livestock	15 gallons per animal
Hogs	4 gallons per hog
Chickens	4 gallons per 100 birds
Turkeys	7 gallons per 100 birds

Quality problems of farm water supplies may be due to physical, chemical, or bacteriological contaminants. The most troublesome contaminants are listed in Table II.

TABLE II — TROUBLESOME FARM WATER CONTAMINANTS

Contaminant	Maximum Tolerable Concentration	Remarks
1. Dissolved Solids	2000 ppm to 3000 ppm	Causes bad taste, highly corrosive.
2. Iron	0.3 ppm	Causes red water. Stains clothing and plumbing fixtures.
3. Iron Bacteria	Nil	Causes red water, clogs pipes and screens, corrodes iron pipes and fittings.
4. Odorous Chemicals	Traces	Causes foul smelling and repulsive drinking water.

1. Family Farm Improvement Branch, Saskatchewan Department of Agriculture, Regina.

5. Sand	Traces	Abrasive water.
6. Calcium & Magnesium	8 gr/gal.	Produces hardness.

The quality problems requiring solutions are vividly described by the farmers themselves.

HIGHLY MINERALIZED WATERS

"About a year and a half ago I had the sewer put in on my farm. Last spring I had trouble with it, the pipe was froze up. I had quite some work with it. A few months later the toilet pipe was leaking. Had it replaced. Cost me quite a bit of money and about three months the same thing again. Now I spoke to the plumbers, they say it cost me $90.00 again to have it replaced. I said I'll wait. There was no inspector around of any kind yet. I suppose I have to have some changing done after it warms up. There sure must be piping that should stand up longer, as this is too much if I have to replace pipes every few months." J.F., Cactus Lake.

"Less than two years ago I had water and sewerage put in on my farm by your branch. This was inspected by government inspector and met with regulations. I find there are objectionable odors outside my house and all my horizontal copper sewage pipes are rotting out. I understand that it is the responsibility of your branch to see that water and sewage works properly." F. O., Beechy.

Two water sources are used on both the above farms. Water for cooking and washing is trucked in and stored in a cistern. Deep wells supply the livestock and toilet flushing water. The water quality of both wells is poor because of excessive mineralization.

	J.F., Cactus Lake	F.O., Beechy
Total Dissolved Solids	3145	3990
Sulfates	1570	2020

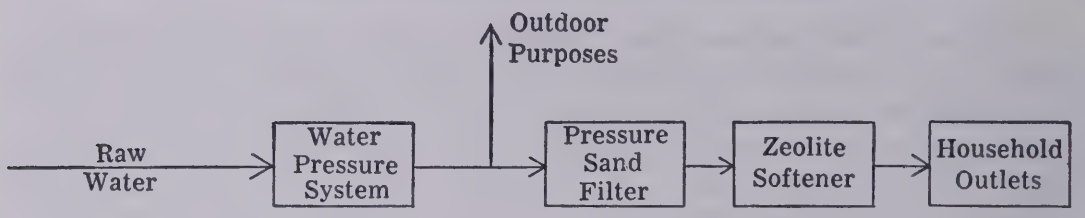
The copper plumbing system corrosion each described is typical of a gas corrosion which occurs on farms where high sulfate water is used.

On farms with highly mineralized waters, it may cost from four to six hundred dollars to live with this problem. A more potable water source must be developed such as a cistern. This then requires a separate pressure system. Also, there is the cost of periodically mending the plumbing system. A dependable farm water demineralizer could correct the problem.

HIGH IRON WATER SUPPLIES

"We have hard water as well as rust in the water. We have heard that rust removers are not satisfactory as they plug up with rust. We have also heard that a large water softener would handle it without a rust remover. We also have a bit of sand in the water. What would you suggest for our problem?" L.G., Paradise Valley, Alta.

Iron removal from farm waters (which are not excessively hard) can be accomplished by the ion exchange process. As diagramed below, all the household water is passed, first through a pressure sand (or an anthrafilt) filter and then through a zeolite softener. The sand filter removes the red suspended iron while the dissolved iron is removed by the resin in the softener.



If the water is very hard the above process is not practical. The only other suitable iron removal process is by a green-stone filter. Such a filter must be regenerated with potassium permanganate. Since this chemical is poisonous, reputable water treatment distributors do not recommend that these filters be used for farm homes.

Experimentation is therefore needed to find a safe regenerant or some other safe method of iron removal.

IRON BACTERIA IN FARM WATER SOURCES

"We put in a pressure system from our well two years ago. We have a heavy slime on top of the water in the toilet flush tank. Also I have found the only way to keep the wash from smelling is to use about ½ cup javex in each load of wash. Where could we send a sample of water to see if this bacteria is our trouble and if so could you give us detailed information on how to deal with the problem?" H.G., Arcola.

"I had a well drilled this spring and when the water was tested it was O.K. but since I've put in the plumbing and pressure system this brown scum and reddish color on everything is present. Please advise me what I can do about this — where to get water tested — how this condition can be overcome." K.A.G., Horizon.

"During the last three years the water, in our present well, has become increasingly reddish to the point when we draw water for a bath in the bath tub, the water is very rusty, red colored and the brown slime is thick on the walls of the toilet reservoir." J.F.C.W., Saskatoon.

Iron bacteria can occur in any farm water source. The organisms can grow in almost any part of the water system — in the well, in the piping or the house plumbing fixtures. If present in extremely heavy concentrations, the iron bacteria will coat well casings, water pipes and plumbing fixtures with brown slimes. The presence of these organisms in the water supplies usually result in adverse tastes and odors.

Information on the occurrance of iron bacteria in Saskatchewan is almost non-existant. A co-ordinated investigation is needed to determine the extent of the problem in the province and to develop dependable detection and preventative methods.

UNSCREENED WELLS

"Please send me a sand point you feel would give me from 8 - 10 gallons of water per minute. Our well was bored through 32 feet clay and small rock and suddenly dropped into this depth of water and quicksand. This came up 20 feet overnight, but in very short time (3 weeks) we had 12 feet of quicksand with 3 - 4 feet of water on top which take about 24 hours to fill up after being pumped out." T.H.B., Carrot River.

"Enclosed please find sand sample from 300 feet down in my well. The water is real nice water for drinking and washing, but I have so much trouble with sand wearing the leathers in my pump. I have a working head on 2 inch drop pipe. Would be very pleased if there was a sand screen that would overcome this." R.A.L., Macklin.

"I am enclosing a sample of sand from my well. This well is a 4 inch hole and is 135 feet deep. We are getting a lot of sand pumped into our water pump and pipes in the house. Could you advise me what number, screen can be used and if it is advisable to use a screen for this fine sand?" SR.T., Fosterton.

Farm wells are not immune from the truth of the old maxim concerning the value of "an ounce of prevention". If all farm wells were screened and developed properly, there would be no sand pumping problem. What approach is needed in overcoming this problem of unscreened wells can only be determined by a field test program.

ODOROUS WATER

"A request has come from discussion at the District Board meeting. A. Rep. District No. 25 for some assistance from the Family Farm Improvement Branch in determining the cause of varying conditions of very bad odor in water from farm dugouts at different times of the year.

Since this area is one that is turning very heavily to rely on dugouts as a source of water the year round, not only for stock but for household and human consumption as well, it appears that this problem will grow and is one that may have considerable bearing on human health as well.

The board would appreciate having all causes of bad water from this source explored so that they might undertake the necessary educational campaign to assist in correcting it". J.O.H., Hudson Bay.

Causes of taste and odor in dugout waters are usually natural. Algae, decaying vegetation, and slime-forming organisms are responsible for the

natural causes. Algae are the most frequent offenders. Decaying vegetation is next in importance (except in warm dugout waters where bacterial slimes may create even more serious odor conditions).

Color, turbidity, bacterial concentration, taste and odor level, hardness, and iron are lowest near the dugout water surface as shown in the water analysis below:

	Surface Water	Filter Well
Color	25 ppm	125 ppm
Turbidity	6 ppm	60 ppm
Dissolved Solids	250 ppm	800 ppm
Hardness	180 ppm	510 ppm
Iron	½ ppm	5 ppm
Taste and Odor Level	Low	High

The most common type of dugout filter used on the prairies withdraws only poor quality bottom water. A dependable floating inlet, to withdraw the high quality surface water, is needed.

RESEARCH NEEDS IN RELATION TO WATER FOR ANIMALS

J. M. Bell[1]

REVIEW OF PRESENT KNOWLEDGE

There is general agreement that the metabolic requirement for water by man and animal is close to 1 ml./calorie of digestible energy consumed when the body exists in the temperature zone of thermal neutrality. At high air temperatures heat dissipation is accomplished by water evaporation through sweating and increased respiration loss, hence water intake must increase correspondingly. At low temperatures the body may have to increase heat production to maintain body temperature. If this is accomplished by increasing food intake, then water consumption must also rise. If heat is produced by robbing the body fat reserves there will be somewhat less free water needed because conversion of fat to heat yields **metabolic** water. In practice, however, loss of 'condition' in animals is generally uneconomical. While recognizing the existence of variations due to environment and animal species, the basic rule of 1 ml./calorie implies that water restriction for any reason will result in decreased feed intake and decreased performance.

RESEARCH NEEDED

Water intake may be a limiting factor through (1) quantity available or (2) quality, with special reference to presence of salts which reduce the assimilation of water from the gastro-intestinal tract into the blood stream or materials which increase the water requirement for urinary excretion. Transfer of fluids from the gastric-intestinal tract to body tissues involves imbibition and syneresis — physical or physical - chemical phenomena relating to osmotic pressures, as well as gel expansion and contraction. Chemicals such as $MgSO_4$ hinder swelling of proteins and therefore inhibit absorption — the net effect being lowered effective nutritive value of the diet, retention of water in the tract and various degrees of laxative action depending on $MgSO_4$ intake. $MgSO_4$ action is manifest mainly through effects on laxation or fecal consistency, neither the Mg nor the SO_4 ion being very effectively absorbed.

Na_2SO_4 acts as both a laxative and a diuretic and is effective therapeutically at about 1/10 the levels used for $MgSO_4$. This may reflect greater assimilation of Na compared to Mg, resulting in increased kidney activity in disposing of the Na imbalance.

Bicarbonates pose new problems. Potentially they may react with HCl of the stomach to yield carbonic acid which is easily disposed of as water and CO_2 but the chloride salt, being highly soluble may eventually end up

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yielding a 'precipitate' of tricalcium phosphate in the gut, since Ca may displace Na for instance and if phosphate is present it may couple with Ca and thus tie up two esential minerals. Such chemistry is probably over-simplified through ignoring the complexity of the entire medium but there is a little supporting evidence.

The matter of tolerance by animals for salts in drinking water is not clear-cut. Animal age, adjustment to water quality, species, mineral content of the dry matter fed, frequency of watering, kind of mineral, etc., are the major factors involved.

A typical index of water quality (Wyo. Bull. 324, 1953) follows:

Good water	Under 1000 ppm solids
Fair (usable)	1000-3000 " "
Poor (usable)	3000-5000 " "
Very poor (questionable)	5000-7000 " "
Not advised	7000+ " "

Highlights of research from elsewhere indicate the unsatisfactory state of current knowledge:

1. MacEwan et al fed rats alkaline water (0.75 vs. 1.4% sodium and magnesium sulfates). The 1.4% level (14,000 ppm) affected bone strength, growth rate and fertility.

2. Bohstedt & Grummer fed up to 2% NaCl in water to pigs to induce salt poisoning. They found the Na ion mainly responsible and found blood Ca level lowered or at least ineffective in maintaining proper nerve function, resulting in symptoms of tetany.

3. Slavin & Warden found 50% NaCl in pig rations (following gradual introduction) to exert no ill effect other than slight diarrhea.

4. Berg & Bowland, (Alta.) fed up to 5,000 ppm of NaCl, $MgSO_4$ and Na_2SO_4 in drinking water for pigs and reported no harmful effects.

5. (a) Stothers (Manitoba) used 10,800 ppm ($CaCl_2$, $MgSO_4$, $NaHCO_3$, $NaNO_3$, Na_2SO_4 mixture) and observed 14% slower gains. No deaths. (25-50 lb. pigs).

   (b) Older pigs (to 180 lb.) had gains reduced only 5%.

   (c) At 15,800 ppm obtained 11% slower gains, 21% poorer feed efficiency and 69% increase in water consumption.

   (d) At 21,300 ppm gains were reduced by 80% and water consumption increased by 100%.

6. The tolerance for saline water appears to be highest for sheep, then cattle, then pigs and horses.

The apparent disagreement noted above may in some way be related to the salts content of the diet as a whole. Water requirements translated from 1 ml/calorie into practical terms means about 2 - 2.5 lb. water/lb.. feed dry matter. Water containing 10,000 ppm salts (1%) would not necessarily be more deleterious to an animal than offering 2% of similar salts in the dry feed. The mineral content of grains and forages ranges from about 2 to 11% to which must be added any supplementary minerals fed.

Research is needed:

1. On methods and feasibility of reducing solids (salts) content of alkaline water to 3,000 ppm or lower,

2. On the reasons for the apparent variation in tolerance of alkalinity by livestock to permit confirmation or revision of the tolerance ratings listed above,

3. On mapping livestock water quality in Saskatchewan so as to provide a general picture of problems that might arise as a result of encouraging increased livestock production.

Progress along these lines would provide evidence regarding our contention that alkali water (and to a lesser extent, hard water) is a serious limiting factor in livestock production in many parts of Saskatchewan and secondly, some hope for overcoming these problems may be found.

WATER RESEARCH NEEDS RELATIVE TO FISH: THE POLLUTION PROBLEM

F. M. Atton[1]

In considering water research needs relative to fish, a definition is first of all necessary — we are not referring to pure water in any sense and if I slip into using that term, let us understand that we are always referring to clean water. Natural waters are by no means pure but most of them are clean waters. In relation to fish, the question of quantity of water is not a major problem from the research approach. In any given section of the country, the possible quantity of water available for fish is more or less fixed; the actual quantity is dependent upon the quality of water and the quality of water is dependent upon the use to which it has been put. We have then the relationship — use produces quality, then quality determines quantity. Relative to fish, water research as a result has two broad categories:

(1) The examination of natural clean water in lakes and streams.

(2) The effects of use and quality of the water where multiple use of water is necessary.

NATURAL CLEAN WATERS

In the first category, research is most important because here we can best observe and experiment with the behaviour and necessary characteristics of the medium. Perhaps I should point out that natural water is not only a physical medium, it is also a nutrient medium and most of the research needs which arise are related in one way or another to this nutrient aspect of the water.

The main research needs on these natural waters are:

(1) The movement of water masses and temperature studies. These are assuming great importance where thermonuclear installations are considered, e.g. the present extensive work being done on Georgian Bay and Lake Huron.

(2) Physical and chemical parameters by which freshwater masses may be identified.

(3) The particular features of autumn storms. These cause great spawning losses in fish populations.

(4) Dissolved substances in the water, especially the main inorganic ions and gases. Saskatchewan is an opportune area for this type of investigation, because of the extreme range in our natural waters. Dissolved solids in some saline water bodies are some 170,000 p.p.m., in other Precambrian lakes 29 p.p.m.

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(5) Light and solar energy relations in water. These seem to be little understood, particularly under the ice cover of winter.

(6) The inter-relations of the environmental factors and the responses of fish. This is the approach of experimental limnology as at the University of Toronto. If use is a criterion of the research a crop is involved, and productivity of the waters at the trophic level of fish is important. Primary productivity investigations may conceivably be supporting studies but alone are not very helpful.

(7) The use of groundwater including brines which could flood natural sloughs and pans to provide for rearing of brine shrimp. This could easily become a 3 to 4 million dollar industry.

To summarize the needs of research on natural waters, let me quote Dr. W. A. Clemens, University of British Columbia — "What seems to be needed is a fundamental study of the relations of light, winds, movements of water masses and amounts of chemical constituents, which result in a high production of phytoplankton". The obvious addition to this list is the conversion of phytoplankton energy to fish and food.

WATER QUALITY AND MULTIPLE USE

The second category of water research needs is concerned with use and quality, where multiple use of waters is necessary. This is the one area where more can be done about quality and conservation of water than anywhere else. You can immediately guess that our main concern here is pollution and we had better define this term. The term does not refer to any sanitation concept or domestic water supply need.

"By pollution is meant the placing in the water of foreign substances which are poisons, deleterious or a nuisance to fish or other organisms" (Clemens, 1961). A great deal of research is being conducted and it would seem that although research must continue, a stage has been reached where education and money are now required. It is against the law to use human excrement for the fertilization of vegetable crops and it should likewise be against the law to use this material for the fertilization of the waters. Municipal sewage disposal plants are difficult to finance, but like industrial procedures will have to have their costs absorbed by the people served or concerned.

A.R.D.A. in a recent publication has summarized the Resources for Tomorrow Conference re waters by saying "Pollution is the most important and critical problem in water use".

The water research needs related to fish are many. I mention broad classes in this category.

(1) Bioassay of waters.

(2) Oxygen demand of natural waters and polluted waters and the satisfaction of this demand.

(3) Toxicity and chronic effects of very dilute solutions.

(4) Mixing of effluents and clean waters, in particular materials that float, as fats, oil, etc.

(5) Synergistic actions of solutes.

(6) Insecticides, herbicides and agricultural fertilizers in waters.

In general the same kind of a laboratory of experimental limnology mentioned is also needed for this category of research needs.

DISCUSSION

The predominant need in water research is a recognition of the ecological approach. In closing may I comment on this:

In the section dealing with water at the Resources for Tomorrow Conference, most authors assume the correctness of the consumptive-non-consumptive concept. They list the consumptive uses, then imply that non-consumptive hydro-developments are the only important utilization of the water that remains. Several of these background papers note recreational use but only two recognize the importance of use by aquatic life. There is a general lack of recognition of the ecological aspects of water use and water research — this in spite of the fact that it is the most extensively used habitat on the globe.

The importance of this appreciation of ecology is emphasized by the forecast published in the United Kingdom last April entitled "The Shape of the Sixties." This 'broadsheet' is from the planning office of the British Government and points out . . . "that in the wider and more effective use of modern techniques too often these have been dominated by the particular outlook and techniques of physics and chemistry and their engineering counterparts". The report insists on an ecological approach to planning instead of acceptance of economic criteria as the only ones of significance in society.

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WILDLIFE RESEARCH NEEDS IN RELATION TO WATER

J. B. Millar[1]

The basic concern of those of us in the wildlife field is the perpetuation of our renewable natural resources for the future enjoyment and benefit of people. In the past, enactment and enforcement of legislation to prevent overharvesting of various game species was considered to be sufficient to ensure their continued survival. Today, however, as human utilization of the land intensifies we are becoming increasingly aware that progressive loss of suitable habitat is now the basic limiting factor for many wildlife species. The resolution of this problem depends first upon our possessing a thorough understanding of the various combinations of environmental factors necessary for the survival of each species and secondly upon our ability to provide these combinations in natural or improved forms in the necessary quantities.

The needs for water research in relation to various types of wildlife are many and varied but today I propose to discuss mainly research needs pertaining to waterfowl since it is that group of wildlife with which the Saskatoon staff of the Canadian Wildlife Service are most intimately involved.

More than one-third of the North American population of game ducks normally breeds in southern Saskatchewan. This resource gives recreation to some 2,000,000 North Americans in the form of hunting and probably to as many more in the form of bird watching and bird photography. Surface water is the basis of waterfowl breeding habitat but the surface water of primary importance to ducks is not reservoirs, rivers and lakes; rather it occurs in pieces less than 10 acres in size. As the numbers of these small water areas decrease, so does the continental duck population — a fact brought sharply into focus by the recent drought in Canada and by widespread drainage in the north central United States. Water research is vital if we are to better understand what constitutes good waterfowl habitat and how to maintain it.

As we delve into the various avenues of research on water relative to its value as waterfowl habitat, it becomes increasingly evident that we must depend to a great extent upon the knowledge, techniques and research of many scientific disciplines to provide the answers we need. Let me give you a few examples. First, we must learn about the factors determining the relative permanence and quality of sloughs and marshes and hence their suitability to waterfowl. Concerning permanence, we find ourselves dependent on the hydrologist, hydrometeorologist and soil scientist to determine the effects of precipitation, runoff, evaporation, seepage, groundwater recharge and discharge, etc. Management of our waterfowl resources can be greatly facilitated if we can devise a method of making short- and long-term predictions of the probable surface water supply for breeding ducks and their broods.

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Concerning the quality of these ponds, we must rely again on the above specialists as well as on chemists, limnologists and plant ecologists to determine variations in water chemistry throughout the season and between years, and the effects of these variations on aquatic invertebrates and vegetation which serve as food, nesting and escape cover for waterfowl. Here we are interested in managing water areas to produce better breeding and brood conditions as well as developing a long-term classification of water areas based on chemical, physical or biological criteria and waterfowl use.

Turning from our needs for research to techniques for evaluating waterfowl habitat, I would like to refer briefly to the problem we face in justifying the continued existence of wetlands for waterfowl and other wildlife. At first glance this may not seem to be a subject for research but further explanation should clarify the point. It is an unfortunate feature of our dollars-and-cents-society that everything seems to have to justify its existence in terms of financial return. An agriculturist can look at a marsh and say that, if drained, it will produce so many dollars worth of grain per acre per year. An engineer can look at the same area and put a precise value on it as an industrial site. The wildlife biologist however is faced with the problem of trying to place a value on such intangibles as relaxation, sport, aesthetics, etc. As the competition for our wetlands increases we in the wildlife field are going to be hard pressed to defend the preservation of these areas unless we can demonstrate that they have other values in addition to the production of wildlife. Possible avenues of research into this problem again involve other disciplines. Groundwater recharge is of particular concern to hydrologists and we must depend on their work to provide an indication of the importance of small surface water areas in recharging the groundwater supply. Wetlands are known to have considerable value for grazing and fodder production but for quantitative evaluation of this we must enlist the aid of agriculturists.

In the past few minutes I have touched briefly on a few of the more pressing needs we have for research on water in relation to ducks. There are doubtless many others but these are the ones we are presently trying to solve through the present wetlands habitat investigation which we are conducting in co-operation with the Saskatchewan Research Council.

In conclusion, I should briefly mention some of the water relationships of other wildlife. It is obvious that some of the most important of Saskatchewan's furbearers — muskrat, beaver, mink and otter, etc. — are as dependent on water as are wildfowl. In a new project aimed at determining the factors affecting fur quality, the Saskatchewan Wildlife Branch will include a study of water. Among big game mammals, moose, in particular, are influenced by water and by aquatic vegetation, which, in spring, makes up 75% of its diet. It is also important to note that water is frequently the environment for one or more stages in the life cycles of some wildlife parasites.

RELATION TO HEALTH OF THE QUALITY OF DRINKING WATER

H. E. Robertson[1]

The Provincial Laboratories, since their establishment in 1905, have been charged with the responsibility to determine whether samples of water submitted by residents were "suitable for drinking purposes". This has required a consideration of physical, bacteriological, and chemical qualities of each water, and, in many instances, a flexible interpretation of the permissible limits for a potable water. Certainly the quality standards expected of public supplies are more stringent than those required for private wells and, for farmers in water-short areas, absence of alternative water supplies may make necessary the use of a water which would not be accepted by less desperate people.

REQUIREMENTS FOR POTABLE WATER

The first concern of health agencies is that the use of a water should not impair the health of the user, either in the short term or after continued use over a period of years. While there is a satisfactory body of knowledge about short term or acute effects of naturally occurring mineral constituents and industrial or domestic chemical residues, there is a dearth of information about long term effects. Only recently have health agencies begun to suspect that common minerals in a water supply might contribute to good health as well as to ill health. Subtle long-term influences are dwarfed by the multitude of factors that influence the health of any population over a period of years. If that were not mask enough, mobility of populations and changes in water sources of even those who stay in one area combine to conceal such influences. I suggest there is need for careful long-term studies of the effect of minerals in drinking water and an opportunity for significant contribution to be made in this province for many residents of Saskatchewan regularly drink highly mineralized water. The mineral content of Saskatchewan waters is much higher than that of waters in most parts of the world, so effects on our population might be quicker to develop and hence easier to recognize than efects on users of less mineralized water.

The first requirement for a potable water is generally assessed by the user. It should be available in adequate quantity and not offend the eye, nose, or palate. Safety is the major criterion, but such physical properties as color, odor, and taste are still important to health. Personal hygiene and general cleanliness are often influenced by the supply of water available. Many groundwaters, particularly seepage wells from surface dugouts, suffer from high iron and pig-pen odors. There is room for research to devise more practical ways of avoiding or correcting these problems.

The second requirement of a potable water is that it should be free of infectious disease agents. Laboratory procedures in use adequately assess

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this hazard in any submitted sample. Granted adequate protection from surface pollution, existing treatment practices of filtration, chlorination, or a combination of the two, meets current needs. While more effective and economical methods may be developed for a particular water, there is not an urgent need for research in this area.

The third requirement for a water to be potable is that it should not contain an excessive amount of mineral or other chemical which would adversely affect the user. It is in this area that the need for further study is most urgent. We need to establish more clearly the levels that constitute "an excessive amount" else we may be underprotecting or overprotecting the sender at his cost. We need also to watch for beneficial effects, for fluorine, iodine, and iron may not be the only minerals that have an optimal level for health of consumers.

THE EFFECT OF DISSOLVED MINERALS ON HEALTH

Let us examine in more detail the thesis that common minerals in a water supply may affect health. It must be admitted, as Dr. Bell has suggested, that the intake of minerals in solid and semi-solid foods generally far exceeds the amounts of minerals ingested in drinking water. Still, the minerals dissolved in drinking water may be absorbed more efficiently. We know that people ingest more fluoride in their foods than in their drinking water, but fluoride in drinking water is more significant in affecting urinary excretion. Tracer studies would seem warranted to determine the relative importance of gastric and intestinal absorption of minerals. Conceivably, predissolved minerals might be appreciably absorbed through the stomach wall. In any case, the sum total of all constituents in food and drink must be considered so all sources are important. Observations that point to the health importance of minerals in drinking water must rely on statistical data whose interpretation is frought with hazards. Mere associations do not prove causal relationships. Still —

(1) Stock(1) reported in 1937 on a study on residents of England and Wales that hardness of water could be statistically related with renal calculi (stones) and cancer of the bladder.

(2) Tromp and Diehl(2) in 1955, and Turner(3) in 1962, reported that water from peaty and moorland surfaces was associated with a higher incidence of cancer of the stomach in residents of such areas, compared to incidence in residents of hard water areas.

(3) Epidemiological studies in Japan(4), United States(5), and Great Britain(6) reported in the past five years have suggested a higher incidence of cardiovascular disease in consumers of soft water than in consumers of hard water. In each study, there were inconsistencies and exceptions to this trend which warn of some other factor being responsible, but such factor could not be found. Criteria of hardness varied in each instance but generally waters with more than 250 parts per million of

hardness (expressed as calcium carbonate) were regarded as very hard. Most people in Saskatchewan drink water much harder. For example:

Prince Albert, Saskatoon, North Battleford	Hardness	200-400 p.p.m.
Regina, Moose Jaw, Yorkton		400-600 p.p.m.
Arcola		1200 p.p.m.
Star City		1600 p.p.m.

In the county boroughs of England and Wales, the evidence was as follows:

Hardness as $CaCO_3$	Death rate from Cardiovascular disorder
less than 50 p.p.m.	654/100,000
100-250 p.p.m.	557/100,000
greater than 250 p.p.m.	543/100,000

Any benefit of increasing hardness seemed to approach a maximum about 250 p.p.m. As pointed out by Schroeder, "any water factor could only be an influence, probably on the course or severity of these disorders, and by no means can be considered as causal at the present time".

Many questions invite answer. Would the correlation hold equally for calcium and magnesium? Marier and Rose(7) of Ottawa have suggested calcium in the water to be beneficial. Neal(8) in Florida conducted a small experiment with rabbits maintained on high fat, high cholesterol diets and either distilled water or water with added magnesium sulphate. Rabbits supplied with the "hard water" developed less atherosclerosis than the rabbits supplied with distilled water. More animal experiments would seem to be indicated with a variety of species of animals to recognize influence of any mineral! Certainly the subject is important enough to warrant such exploration!

(4) Finally, I would like to comment on findings of a preliminary field study carried out in Saskatchewan(9) in 1960.

A mobile clinic-laboratory visited a number of communities in Saskatchewan with a record of highly mineralized water supplies. In each of these communities were to be found a number of enterprising or fortunate individuals with a much less mineralized water supply. Geographical, occupational, and ethnic origins of the two groups were not significantly different. Adults who had been using a single water supply (not both) for a minimum of ten years were offered a physical examination in exchange for a sample of their drinking water, urine and blood. Waters were tested for hardness, alkalinity, and iodine content. Patients' histories were prepared and compared for cystolic blood pressure, hypertensiveness, thyroid, kidney, and gastro-intestinal disorder. X-rays or function tests were **not** taken.

No correlation could be found between total dissolved solids and any disorder. But we were surprised to find in the small study of 697 adults that people who regularly consumed water of more than 500 p.p.m.

hardness had a five to tenfold greater incidence of gastrointestinal disorders compared to users of waters with less than 300 p.p.m. of total hardness. Unfortunately, we did not make separate determinations of calcium and magnesium at the time, nor did we assay for sulphate ion. We therefore cannot suggest that hardness alone was related, or that sulphate might not have been more important. However, sulphate usually correlates well with total dissolved solids, and here there was no correlation. The possibility of other unrecognized factors or trace elements was not ruled out.

There is obviously much room for further studies in this area. The United States Public Health Service list a permissive limit of total dissolved solids of 1000 p.p.m. whenever a less mineralized water is not available. The World Health Organization Committee on International Standards for Drinking Water in 1963 adopted 1500 parts per million as the "maximum allowable concentration". Probably more than 1/3 of Saskatchewan residents regularly ingest waters with greater amount. Need we be concerned or drive our people to desperate efforts and greatly increased expenditure to find a better water? Should we recommend that residents of areas where drinking waters are very hard should at least partially soften their drinking water? May we defend the peculiar occasional recommendation of differing agencies that a highly mineralized water of "poor" quality be tolerated for human consumption but not recommended for domestic livestock or poultry? I submit that controlled studies are needed of the effect of minerals in drinking water on the health of domestic animals and poultry.

Finally, very little is known of the prevalence of some of the more important trace elements in water. Survey would seem to be warranted to determine the concentrations of such minerals as boron, manganese, cobalt, copper, thallium, lead, and selenium to mention only a few. Our laboratory hopes in the near future to put an atomic absorption spectrophotometer into service that may allow rapid scanning for many of these constituents.

In conclusion, the most inviting areas for research are the effect of dissolved minerals in drinking water on the health of consumers. Effects suggested by studies to date may be illusionary, but certainly warrant more thorough investigation.

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